Consumer-Friendly and Environmentally-Sound Electricity Rates for the Twenty-First Century

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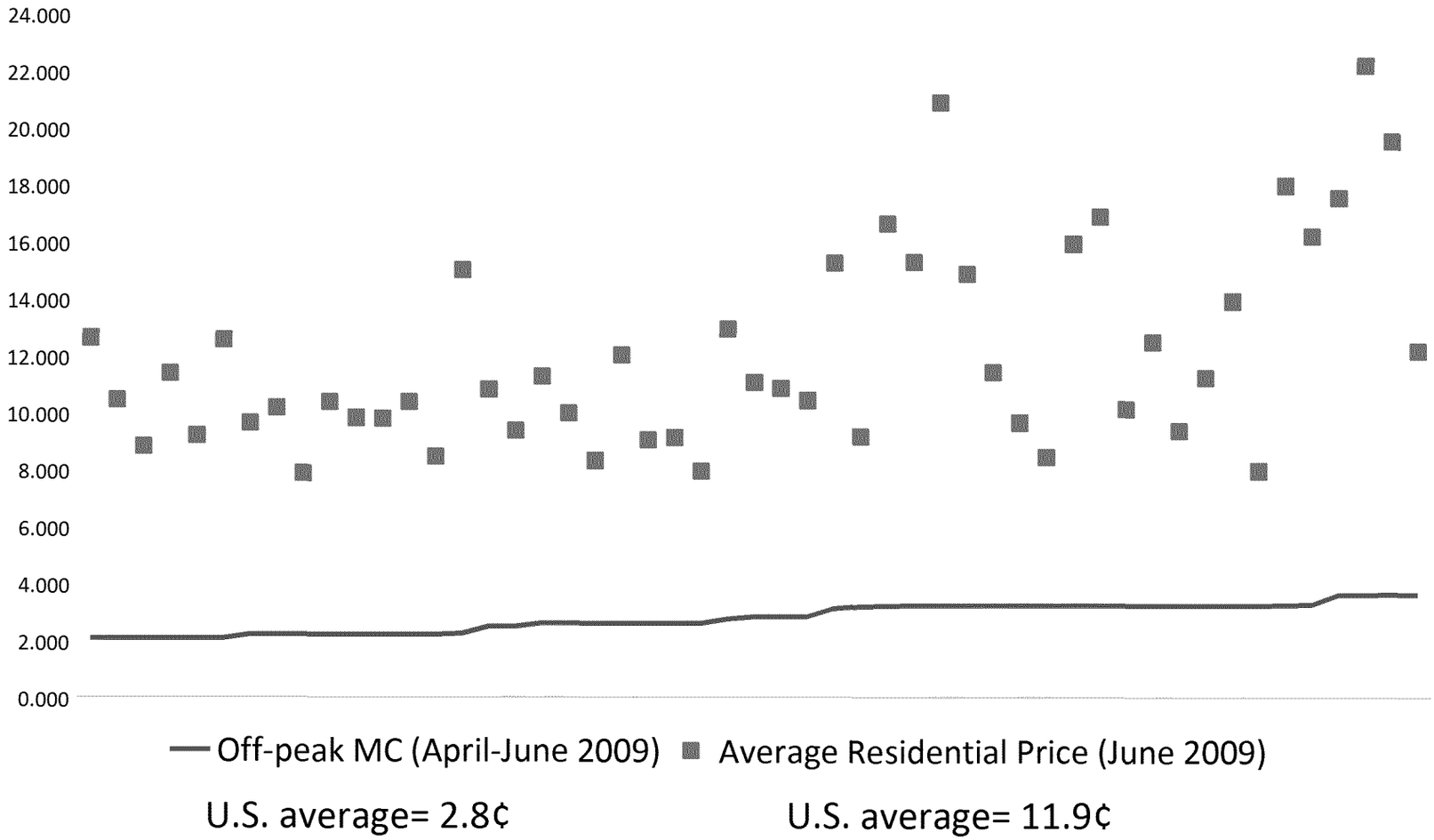
Paper available for download now on my personal homepage at the Goldman School:
http://gsppi.berkeley.edu/faculty/lfriedman/lee-s-friedman
This paper builds on Lee S. Friedman, "The Importance of Marginal Cost Electricity Pricing to the Success of Greenhouse Gas Reduction Programs" Energy Policy, 39, No. 11, November 2011, pp. 7347-7360.

Overview

- The Importance of Marginal Cost Electricity Pricing (off-peak emphasis, e.g. vehicle electrification)
- Time-varying residential electricity rates have been unpopular
- Are there efficient, fair and practical time-varying rate designs that would be popular (suitable for widespread use, like as a default plan)?
- Designs that I call HOOP (Household On and Off Peak) plans are efficient and have the potential to be fair and practical. HOOP plans
  - (1) utilize marginal-cost based time-varying rates, and
  - (2) assign fixed infrastructure charges that vary by customer group in accordance with commonly used equity principles
- I test these plans on a statewide representative sample of 331 California residences for which usage data is available every 15 minutes for one year.
- Simple HOOP plans applied to the statewide sample can result in bills that replicate reasonably closely the bills from the far more complex rate plans of the three independent utilities that serve California
- Conclusion: It seems promising that utilities and utility commissions can utilize HOOP designs to create default and optional time-varying rate plans with widespread acceptance

Electricity Rates are 2x-6x higher than Off-peak Marginal Costs in the U.S.



U.S. average= 2.8¢

U.S. average= 11.9¢

The Unpopularity of Time-Varying Rates

- Time-Varying Rates became of substantial interest during 1970s
  - following OPEC oil embargo
  - concern for energy security and energy conservation.
  - U.S. DOE sponsored 15 residential TOU projects starting with Vermont 1975
  - Attention was on how responsive residences would be, not how attractive the plans would be.
  - Used volunteers, not representative of residential populations
- Many utilities began and have continued to offer optional time-varying programs
- Federal Energy Regulatory Commission survey 2010: Only 1% of U.S. Residential population on time-varying rates.
- Renewed interest among policy-makers with concerns about GHGs and energy security. Technological advance makes "demand responsiveness" much easier--smart grid, smart meters, smart appliances (e.g. automatically work less hard during the peak). CT and CA initiated efforts to make time-varying rates either mandatory (CT) or the default rate (CA).
- But some consumer groups strenuously resist efforts, fear high bills, worry about effects on vulnerable populations, the less educated. Both CA & CT PUCs have had to delay their attempted transitions to time-varying rates.
- The open question: is it possible to design time-varying rates that are practical, fair and efficient for substantial portions of the residential population?

California sample

- Statewide Pricing Pilot 2003-04
  - Designed to test critical peak pricing
  - Collected 16 month of continuous usage data measured in 15 minute increments.
  - Control group designed to be representative of state as whole (stratified sample). N=331
  - Mean monthly kWh usage = 543.29, bill = $71.72
  - Mean monthly peak usage (2-7PM) = 95.20 (17.5%), off-peak usage 448.09 (82.5%)

Figure 2: The System Load is Declining before the Residential Load has Reached its Peak

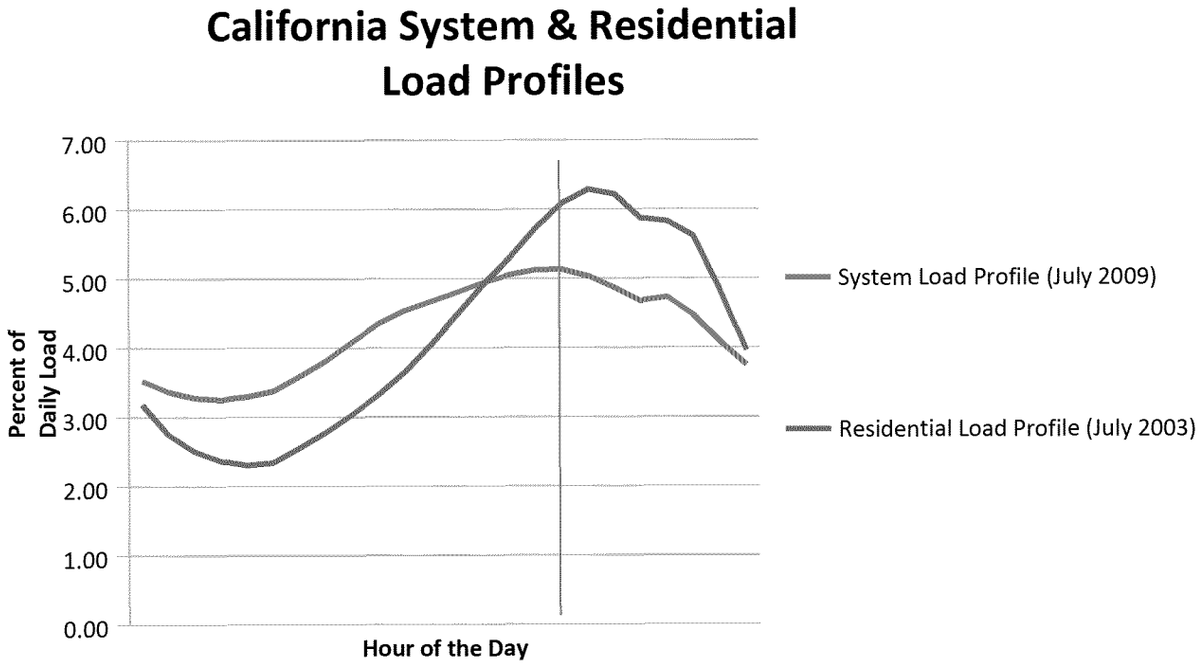
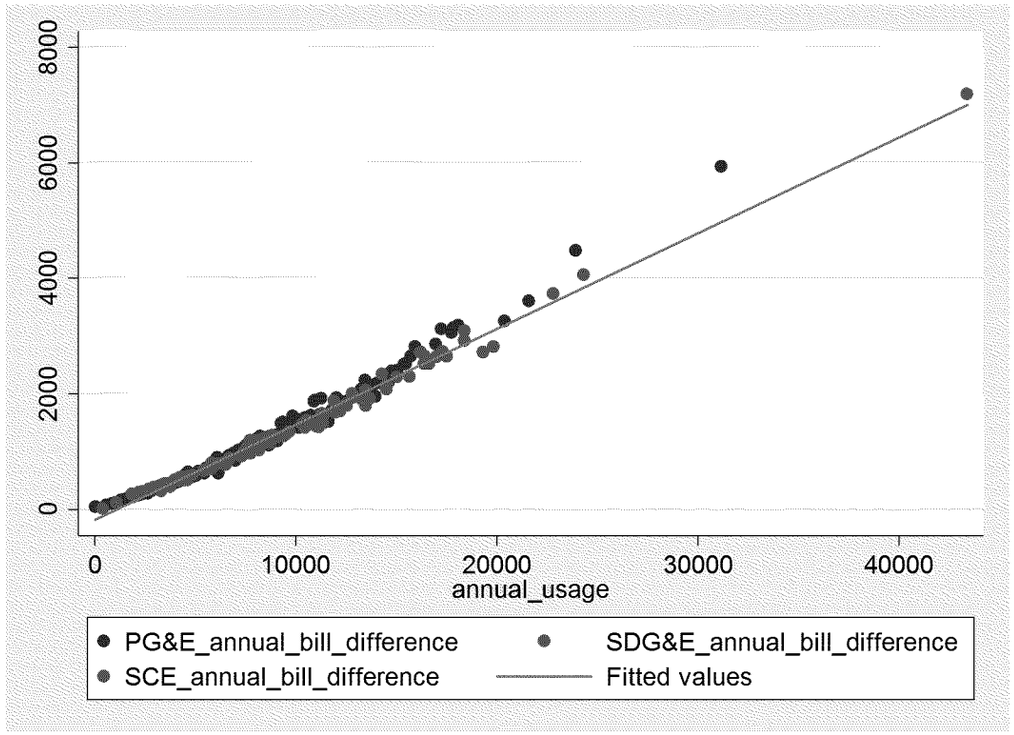


Table 3: No "Law of One Price" in Existing California Electric Rates
(price incentives at identical usage vary by more than 100% because of complex rate structures)

Monthly Usage (kWh)	Baseline Quantity	Classification	Bill	Marginal Price per kWh
700	714	CARE, All-electric, Bakersfield	$58.21	$.092
700	561	CARE, Basic, Bakersfield	$59.95	$.106
700	312	CARE, All-electric, Santa Cruz	$63.05	$.106
700	219	CARE, Basic, northeast CA	$64.21	$.106
700	714	All-electric, Bakersfield	$79.31	$.126
700	561	Basic, Bakersfield	$81.48	$.143
700	312	All-electric, Santa Cruz	$96.94	$.210
700	219	Basic, northeast CA	$107.43	$.210

Figure 3: Despite Complex Rate Variations across Customers , Annual Usage Predicts Annual Bills

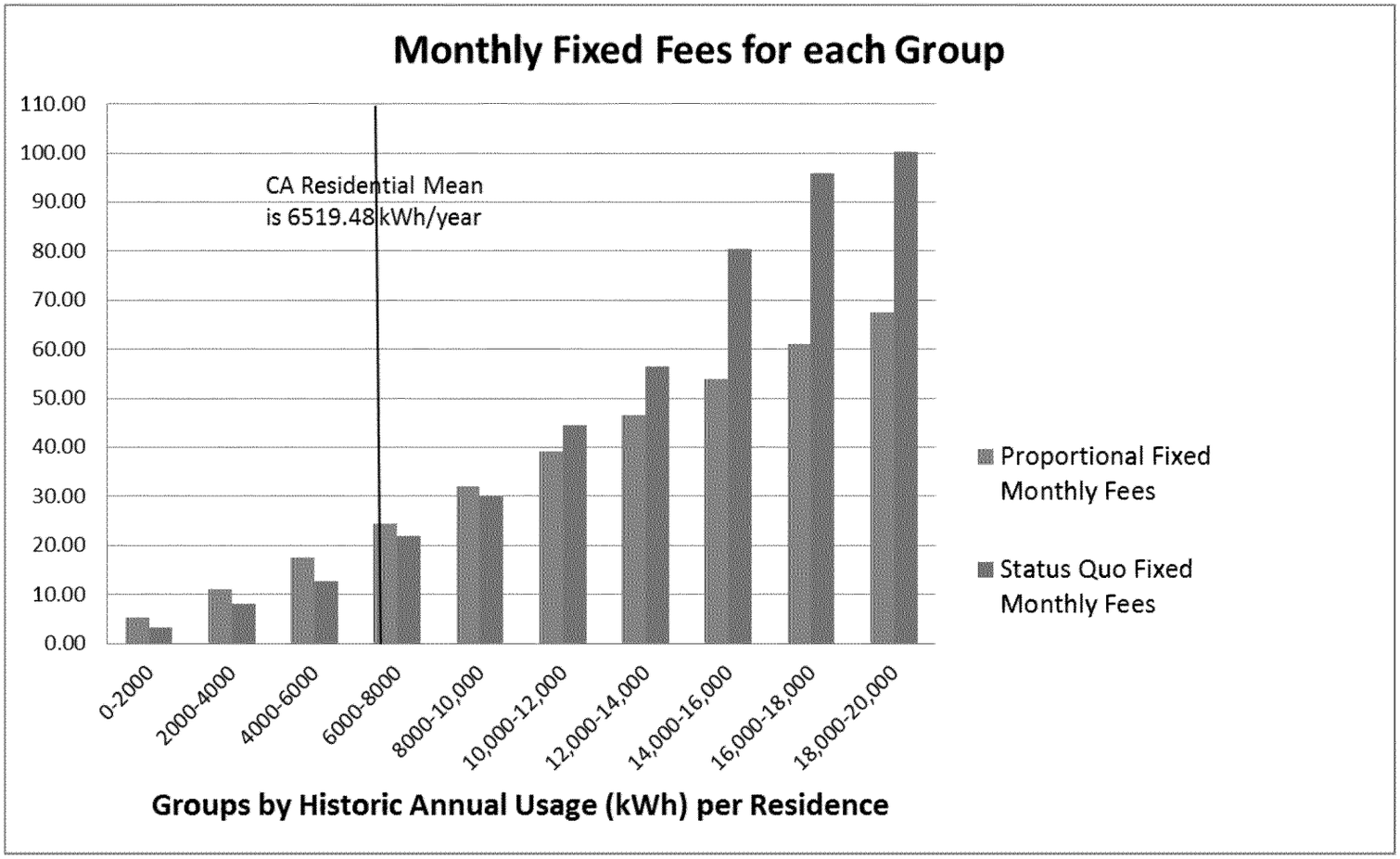


Annual Bill = -184.7551 + .1654821*Annual Usage R^2 = .98
(33.26) (.005)

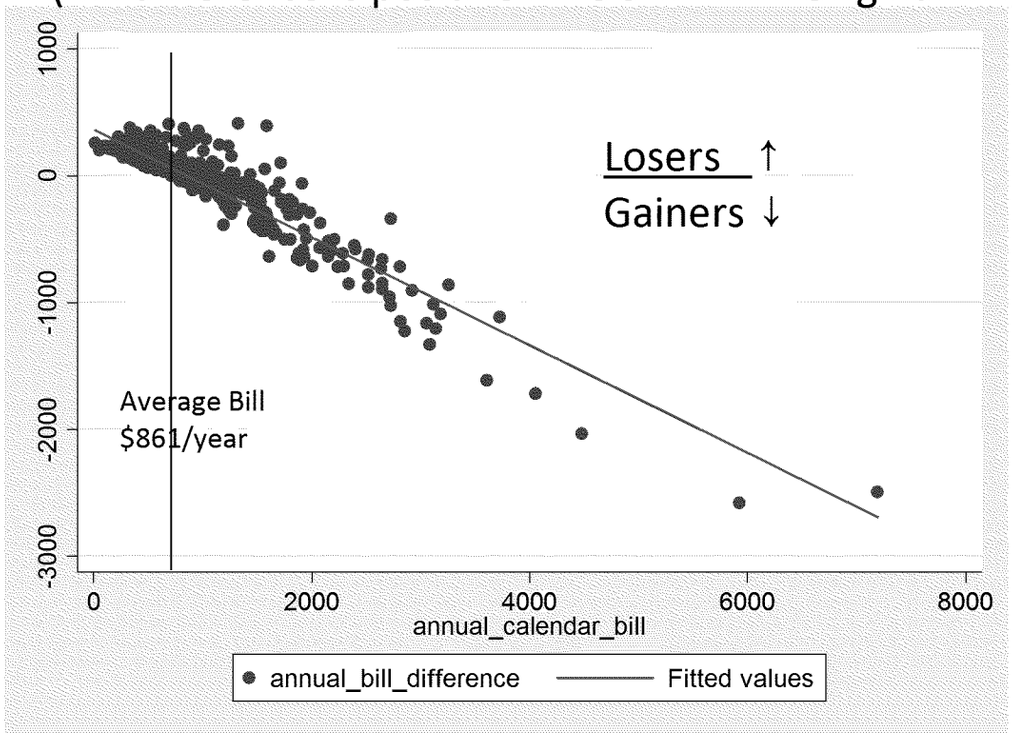
Table 4: HOOP Fixed Fees
(revenue-neutral compared to status quo, average annual fixed fee of $249.12)

Group (Annual kWh)	Proportional Fixed Fees (Annual Non-CARE)	Proportional Fixed Fees (Annual CARE)*	Status Quo Equity Fees (Annual Non-CARE)	Status Quo Equity Fees (Annual CARE)*
0-2000	62.85	-2.78	38.10	20.83
2000-4000	133.09	-5.88	96.46	-5.40
4000-6000	209.70	-9.27	152.84	-28.60
6000-8000	294.19	-13.01	263.72	-33.67
8000-10,000	385.85	-17.06	358.78	81.12
10,000-12,000	469.57	-20.76	533.35	-15.95
12,000-14,000	557.87	-24.67	677.82	8.32
14,000-16,000	647.13	-28.61	965.57	259.81
16,000-18,000	732.24	-32.37	1149.97	12.74
18,000-20,000	810.28	--------	1202.96	-------

* Based on small CARE sample size (n=54, 16.3% of sample, 14.9% of population), may not be representative. Status quo equity fees can be skewed because of very few CARE residences in a group.

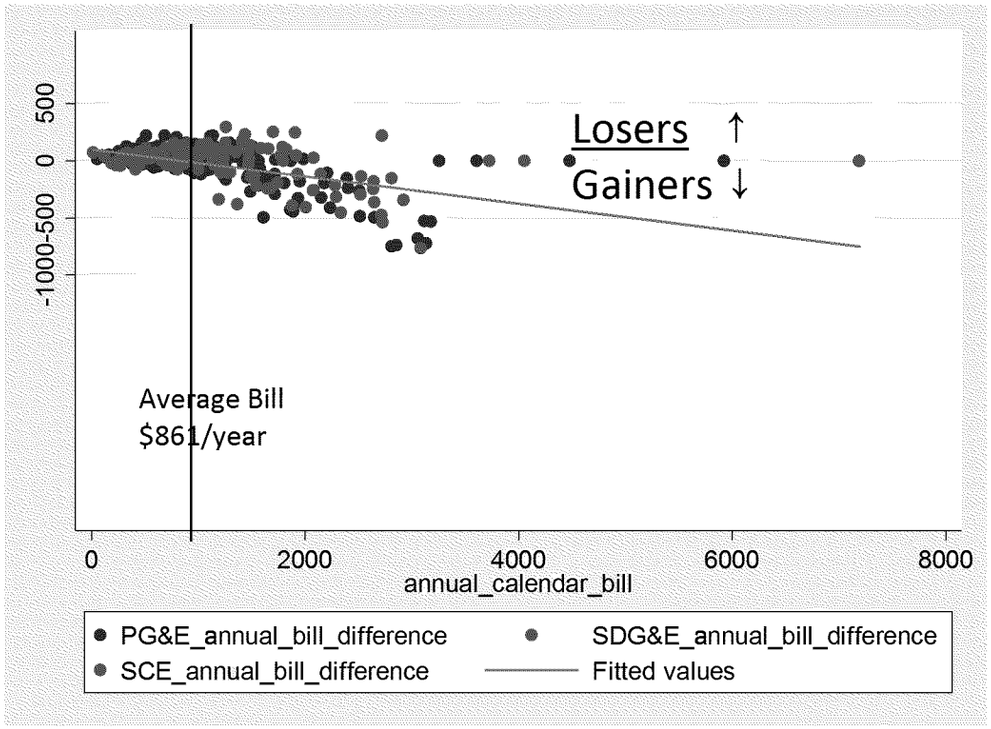

Monthly Fixed Fees for each Group
110.00
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
CA Residential Mean
is 6519.48 kWh/year
0-2000
2000-4000
4000-6000
6000-8000
8000-10,000
10,000-12,000
12,000-14,000
14,000-16,000
16,000-18,000
18,000-20,000
Groups by Historic Annual Usage (kWh) per Residence
Proportional Fixed Monthly Fees
Status Quo Fixed Monthly Fees

TOU 2-7PM Peak Plan ($.30/kWh peak, $.05/kWh off-peak)
Applied to Representative California Residential Population
Regressive TOU27 Bill Differences with **Standard Two-Part Tariff Fixed Fee**
$249.12 annually or $20.76 monthly
(Bill difference is positive if TOU27 Bill > Original Bill)



Difference = 366.0315 - .4252*Bill R^2 = .86
(10.49) (.01)

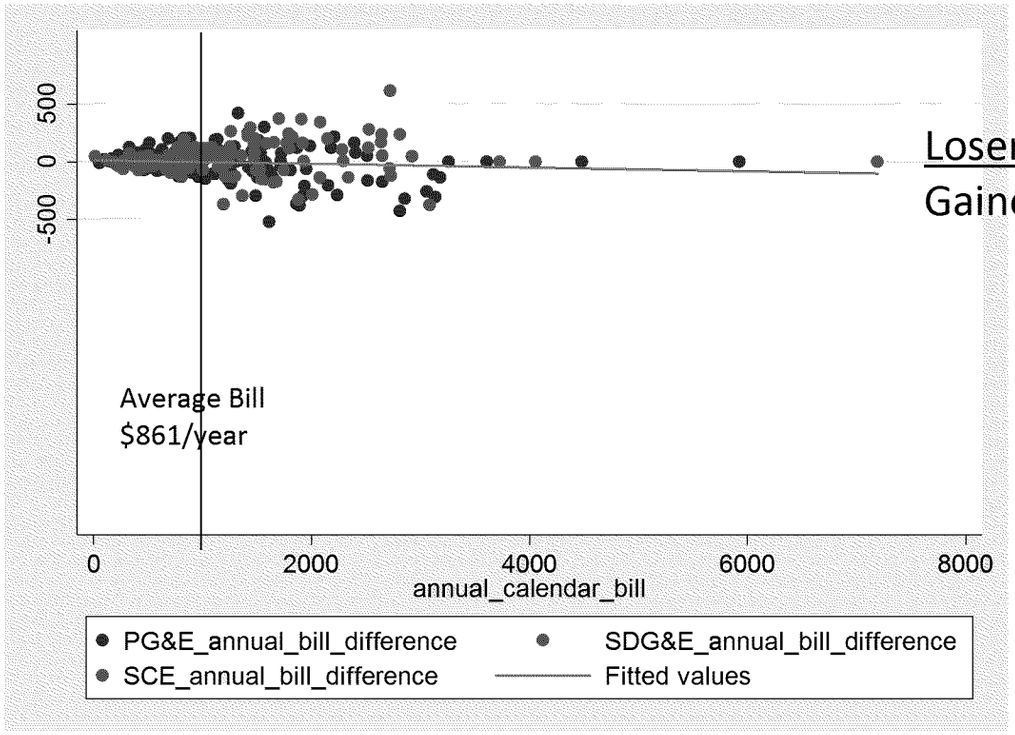
Figure 6: Graph of Absolute Bill Differences caused by Proportional Fee



$Y = 102.1494 - .1186939\ X$ $\qquad R^2 = .32$

(10.40) (.01)

TOU 2-7PM Peak Plan ($.30/kWh peak, $.05/kWh off-peak)
Applied to Representative California Residential Population
The **Status Quo Equity Rule** is neutral with respect to small and large users in terms of bill differences caused by a switch to a TOU27 plan



Difference = 14.5227 - .0159069Bill R^2=.01
(9.42) (.01)

Table 3: Annual Bill Differences Caused by Alternative HOOP Rate Designs are Reasonably Small

Bill Difference =Time-Varying Bill – Time-Invariant Bill

(Negative Numbers Gainers, Positive Numbers Losers)

Percentile	Uniform Fixed Fee	HOOP Proportional Fixed Fee	Percent Bill Change at Decile Median	HOOP Status Quo Equity Fee	Percent Bill Change at Decile Median
0-10	-748.17	-349.43	-16.99	-214.85	-13.93
10-20	-215.37	-78.77	-7.91	-67.61	-8.94
20-30	-64.27	-18.29	-2.51	-37.11	-6.47
30-40	13.90	6.11	1.45	-16.31	-3.60
40-50	75.33	23.66	5.73	-2.86	-.14
50-60	107.98	39.09	8.91	10.37	2.77
60-70	142.27	52.01	9.98	26.49	4.33
70-80	175.72	70.82	12.26	45.46	7.91
80-90	216.82	93.78	11.47	78.19	9.15
90-95	264.84	131.86	17.03	133.42	11.07
95-99	311.32	173.80	17.87	209.76	16.73
99-100	377.03	249.12	15.98	353.59	19.30

Other issues in the design of HOOP rates

- How dynamic?
  - Illustrations are for simple peak and off-peak plans, but same logic applies to a more dynamic plan like critical peak pricing—a version that might be preferable as the default option.
- How historical should the baseline be for assigning individuals to groups?
  - Three-year moving average good for avoiding using an unusual weather year as a baseline.
- How complex should the criteria be for group assignments, apart from usage levels?
  - California utilities divide their service territories into climate zones (SCE has 9, PG&E 10, SDG&E 4) and baseline quantities are set separately for each zone. If this categorization is an accepted equity norm, then HOOP fee structures should also be made specific to each climate zone. (Utilities can do this easily, sample size of this study is too small to simulate this)
- How do these apply in restructured areas with retail electricity competition?
  - Needs further investigation, but restructured areas divide charges into a nonbypassable component used to collect non-energy charges, and then competitively set energy charges. The HOOP infrastructure charges would apply to the nonbypassable charge, and then the energy charges would be time-varying but competitively set. The “standard offer” should be one with time-varying rates.

Conclusions

- Workable, fair and efficient time-varying residential rates need to replace outmoded time-invariant rates.
  - Huge disconnect between off-peak rates and off-peak marginal costs wrongly discourages vehicle electrification
  - The smart grid makes demand responsiveness much easier and more automated, but need right price signals
- Residences have avoided time-varying rates in part due to fear of high bills.
- HOOP plans utilize marginal-cost based time-varying rates and a set of infrastructure fees designed to be equitable across a broad population.
- Using a representative sample of California residences, I find that simple statewide HOOP designs
  - are able to replicate reasonably closely the bills from the time-invariant system. The utilities can tailor these to each climate zone to get a much closer fit.
  - can be neutral in the sense of not systematically favoring either low or high usage customers
  - can also be neutral by income level, illustrated here by neutrality with respect to CARE (low-income) customers and non-CARE customers.
- HOOP designs are promising as a method for making rates that
  - are attractive to large numbers of customers
  - address important environmental issues by bringing off-peak rates down to marginal costs
  - take advantage of the smartening grid by providing the right signals for demand responsiveness